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(54) **CALIBRATION VIAL AND TECHNIQUE FOR CALIBRATING A FIBER OPTIC OXYGEN SENSING NEEDLE**

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(58) **Field of Classification Search**
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See application file for complete search history.

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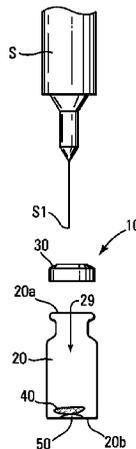
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(57) **ABSTRACT**

A calibration tool and method of using the tool to calibrate a fiber optic needle oxygen sensor. The tool includes at least a vial sealingly covered by a septa and containing a supply of particulate oxygen getter within the chamber of the vial. The vial has an open top and is constructed from an oxygen impermeable material. The septa is resealing, needle-penetrable and oxygen impermeable. The supply of particulate oxygen getter is retained within an oxygen permeable sachet.

21 Claims, 1 Drawing Sheet



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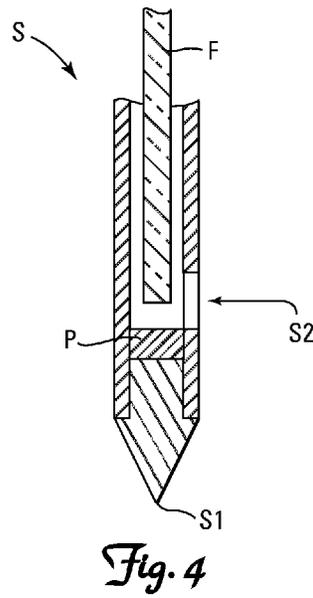
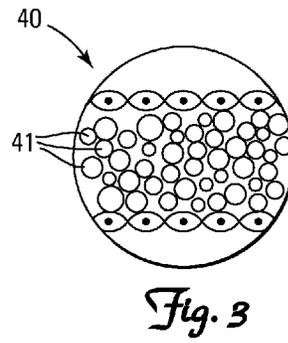
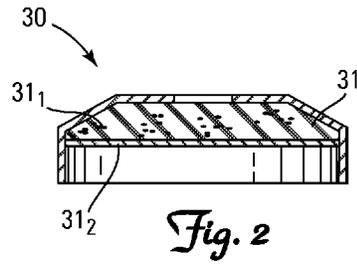
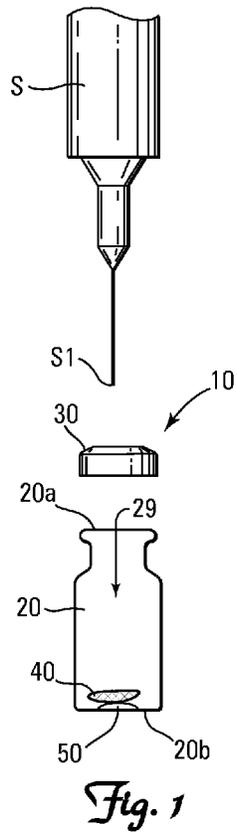
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CALIBRATION VIAL AND TECHNIQUE FOR CALIBRATING A FIBER OPTIC OXYGEN SENSING NEEDLE

BACKGROUND

Photoluminescent sensors or probes are a widely employed method of measuring analyte concentration, typically oxygen, within an enclosed space such as a package, container or living tissue. Briefly, analyte concentration within a package or container can be measured by inserting an analyte sensitive photoluminescent probe within the package, container or tissue, allowing the probe to equilibrate within the package, container or tissue, exciting the probe with radiant energy, and measuring the extent to which radiant energy emitted by the excited probe is quenched by the presence of the target analyte. Exemplary optical sensors are described in WO 92/19150 and CA 2,600,563. Such optical sensors are available from a number of suppliers, including Presens Precision Sensing, GmbH of Regensburg, Germany, Oxysense of Dallas, Tex., United States, and Luxcel Biosciences, Ltd of Cork, Ireland.

Analytical instruments used to read such photoluminescent probes are commonly programmed with a calibration mode that permits calibration of the instrument by having the instrument read probes that have been exposed to mediums having known concentrations of the target analyte (e.g., setting the instrument to calibration mode, reading a probe that has been placed within a container that is flushed with certified tank gas containing 0% analyte, and then reading a probe that has been placed within a container that is flushed with certified tank gas containing a known concentration(s) of analyte such as 100% analyte).

While effective for accurately calibrating optical sensors, this calibration method is time consuming and expensive.

Accordingly, a substantial need exists for a low cost system and method for accurately and reliably calibrating instruments used to read photoluminescent sensors or probes.

SUMMARY OF THE INVENTION

A first aspect of the invention is a calibration tool for use in obtaining a zero calibration value for a fiber optic needle oxygen sensor. The calibration tool includes a vial sealingly covered by a septa and containing a supply of particulate oxygen getter within the chamber of the vial. The vial has an open top and is constructed from an oxygen impermeable material. The septa is resealing, penetrable by a fiber optic needle oxygen sensor, and oxygen impermeable. The supply of particulate oxygen getter is retained within an oxygen permeable sachet.

A second aspect of the invention is a method of calibrating a fiber optic needle oxygen sensor having an oxygen sensitive photoluminescent probe proximate the tip of the needle. The calibration method includes the steps of (a) setting the sensor to calibration mode, (b) obtaining a span calibration value by (i) placing the photoluminescent probe on the sensor in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with a fluid having a known non-zero partial pressure of oxygen, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and (c) obtaining a zero calibration value by (i) placing the photoluminescent probe on the sensor in fluid communication with the chamber of a calibration tool in accordance with the first aspect of the invention by inserting the needle through the

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septa on the calibration tool, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with the chamber of the calibration tool, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded side view of one embodiment of the invention depicted in combination with a fiber optic needle oxygen sensor.

FIG. 2 is an enlarged cross-sectional side view of the cap component of the invention depicted in FIG. 1.

FIG. 3 is a grossly-enlarged cross-sectional side view of a portion of the sachet component of the invention depicted in FIG. 1 showing the particulate oxygen getter contained within the sachet.

FIG. 4 is a grossly-enlarged cross-sectional side view of the tip of the fiber optic needle oxygen sensor depicted in FIG. 1.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Definitions

As used herein, including the claims, the phrase "oxygen impermeable" means a material that when formed into a 1 mil (25.4 μm) film has an oxygen transmission rate of less than 10 cm^3/m^2 day when measured in accordance with ASTM F 1927.

As used herein, including the claims, the phrase "oxygen permeable" means a material that when formed into a 1 mil film has an oxygen transmission rate of greater than 1,000 cm^3/m^2 day when measured in accordance with ASTM D 3985.

As used herein, including the claims, the phrase "oxygen barrier" means a film, including coated, metalized and multiple layer films, that are impervious to oxygen (such as a layer of metal) or have an oxygen transmission rate of less than 0.1 cm^3/m^2 day when measured in accordance with ASTM F 1927.

As used herein, including the claims, the phrase "near zero", when used to describe a concentration of oxygen in a sample, means less than 0.01% oxygen.

As used herein, including the claims, the phrase "oxygen sensitivity" or "sensitivity to oxygen" means sensitivity measured by luminescence quenching.

As used herein, including the claims, the phrase "thin film" means a film having a thickness of less than 10 μm .

As used herein, including the claims, the phrase "small container" means a container will a fillable volume of less than 20 ml.

Nomenclature

10 Calibration Tool

20 Vial

20a Open Top of Vial

20b Bottom of Vial

29 Vial Retention Chamber

30 Cap

31 Septa

31₁ Resealable Layer of Septa (Elastomer)

31₂ Oxygen Barrier Layer of Septa (Metal Foil)

40 Sachet

41 Particulate Oxygen Getter

50 Confirmation Photoluminescent Oxygen Probe

S Fiber Optic Needle Oxygen Sensor

S₁ Tip of Fiber Optic Needle Oxygen Sensor

S₂ Side Port In Fiber Optic Needle Oxygen Sensor

F Fiber Optic Filament
P Photoluminescent Oxygen Probe
Construction

FIG. 1 depicts a calibration tool **10** constructed in accordance with the invention. The calibration tool **10** includes a vial **20**, a cap **30** and a sachet **40** containing a particulate oxygen getter **41**.

The vial **20** or other suitable container has an open top **20a** and a closed bottom **20b**. The vial **20** preferably has a fillable volume of less than 50 ml, with a preference for small containers having a fillable volume of between 2 and 20 ml.

The vial **20** can be constructed from substantially any oxygen impermeable material possessing the necessary structural integrity. The vial **20** is preferably constructed from an oxygen barrier material for reducing the rate at which oxygen permeates through the walls of the vial **20** and into the chamber **29** defined by the vial **20**. Suitable materials include specifically, but not exclusively, glass and certain plastics. Glass is preferred.

Referring to FIGS. 1 and 2, the open top **20a** of the vial **20** is sealingly covered by a cap **30** with a septa **31** or other suitable sealing device. In addition to sealing off the chamber **29** of the vial **20** from the surrounding environment, the cap **30**, and in particular the septa **31** on the cap **30**, needs to be impermeable to oxygen—at least prior to being penetrated by the tip S_1 of a fiber optic needle oxygen sensor **S**, and reseal after being penetrated by the tip S_1 of a fiber optic needle oxygen sensor **S**. Use of a cap **30** which is not impermeable to oxygen can significantly reduce the useful lifespan of the calibration tool **10** by rapidly utilizing the oxygen getter retained within the chamber **29** even prior to use, and in egregious cases can transmit oxygen at a rate faster than the oxygen getter **41** retained within the chamber **29** can scavenge the oxygen, causing the oxygen concentration within the chamber **29** to almost instantaneously rise well above zero. Use of a cap **30** which cannot reseal after being penetrated by the tip S_1 of a fiber optic needle oxygen sensor **S** effectively renders the calibration tool **10** an expensive single use disposable item as oxygen from the surrounding environment will readily pass through the hole left in the cap **30** after a single fiber optic needle oxygen sensor **S** is calibrated with the calibration tool **10**.

Referring to FIG. 2, one type of cap **30** capable of providing both the desired resealing and oxygen impermeable characteristics is a cap **30** with a septa **31** comprised of a layer of resealing elastomer **31₁**, such as synthetic silicone rubber, with a layer of an oxygen impermeable material **31₂**, such as a metal foil, laminated to the underside thereof. Caps **30** with such dual functional septa **31** are available from a number of sources, including Sigma-Aldrich and Fisher Scientific. The cap **30** can be selected from any style cap including specifically, but not exclusively screw and crimp style caps, with crimp style caps generally preferred.

Referring to FIGS. 1 and 3, particulate oxygen getter **41** is provided within the chamber **29** of the vial **20** for consuming any oxygen that reaches the chamber **29** through the vial **20** and/or the cap **30** in order to maintain the concentration of oxygen within the chamber **29** at near zero.

The oxygen getter **41** can be selected from any known oxygen getter, including specifically but not exclusively activated carbon, silica gel, activated alumina, molecular sieve, metals such as iron, magnesium, zinc and titanium, and various inorganic salts of such metals.

As is known to those of routine skill in the art, a particulate hygroscopic material (not shown) is frequently employed in combination with a particulate oxygen getter **41** as many oxygen getters **41** require water in order to chemically react

with and scavenge the oxygen, and water absorbed by a hygroscopic material can provide the necessary supply of water.

The oxygen getter **41** must have an oxygen consumption rate that exceeds the permeation rate of oxygen into the chamber **29** from the surrounding air. Generally, the oxygen getter **41** preferably consumes oxygen at a rate that is only slightly greater than the permeation rate of oxygen into the chamber **29**, with a generally acceptable range of between two to ten times the permeation rate of oxygen into the chamber **29**. One of the factors that impacts the speed with which the oxygen getter **41** can scavenge oxygen within the chamber **29** is the surface area of the oxygen getter **41**. In order to provide a surface area effective for scavenging oxygen reaching the chamber **29** at a rate that is at least as fast as the rate at which oxygen permeates into the chamber **29** from the surrounding air, the oxygen getter **41** is preferably provided in particulate or powdered form with an average particle size of less than 10 mil, preferably 1-5 mil and most preferably 1-3 mil. However, when provided in this form I discovered that the particulates have a tendency to diffuse into and coat the probe **P** and fiber optic filament **F** on fiber optic needle oxygen sensors **S** inserted into the chamber **29** containing these particulates, with a concomitant reduction in the accuracy and sensitivity of the contaminated sensor **S**. Referring to FIGS. 1 and 3, I discovered that this drawback could be eliminated, without significantly impacting the oxygen scavenging performance of the particulate oxygen getter **41**, by retaining the oxygen getter **41** in an oxygen permeable sachet **40**. Such sachets **40** filled with particulate oxygen getter material **41** are commercially available from a number of suppliers, typically sold for purposes of protecting packaged foods, including Multisorb Technologies under the designation FreshPax®.

The outside of the vial **20** can be imprinted with indicia (not shown) identifying the vial **20** as a zero-calibration tool **10** (e.g., “0% O₂”, “Zero O₂”, etc.).

One of the factors impacting the lifespan of the calibration tool **10** is the ratio of oxygen getter **41** to chamber size **29**. A lifespan of at least one year from sealing of the chamber **29** or 100 uses, whichever occurs first, is generally desired. In order to reach this desired lifespan, a weight/volume ratio of oxygen getter **41** to sealed chamber **29** of 1:5 to 1:20 mg/cm³ is generally effective, with a weight/volume ratio of 1:10 to 1:20 mg/cm³ generally preferred.

The calibration tool **10** can optionally be equipped with a confirmation probe **50** within the chamber **29** for allowing the oxygen concentration within the chamber **29** to be checked by interrogating the confirmation probe **50** with a photoluminescent reader (not shown).

Vials **20** equipped with a confirmation probe **50** within the chamber **29** need to be transparent or translucent at least at the specific wavelengths at which the confirmation probe **50** absorbs and emits energy.

The oxygen sensitive confirmation probe **50** can be constructed in accordance with standard convention by embedding an oxygen-sensitive photoluminescent dye (not shown) within an oxygen-permeable carrier matrix (not shown).

The oxygen-sensitive photoluminescent dye (not shown) may be selected from any of the well-known oxygen sensitive photoluminescent dyes used in the construction of oxygen sensitive photoluminescent probes. A nonexhaustive list of such oxygen sensitive photoluminescent dyes (not shown) includes specifically, but not exclusively, ruthenium(II)-bipyridyl and ruthenium(II)-diphenylphenanthroline complexes, porphyrin-ketones such as platinum(II)-octaethylporphyrin-ketone, platinum(II)-porphyrin such as platinum(II)-tetrakis(pentafluorophenyl)porphyrin, palladium(II)-

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porphyrin such as palladium(II)-tetrakis(pentafluorophenyl) porphine, phosphorescent metallocomplexes of tetrabenzoporphyrins, chlorins, azaporphyrins, and long-decay luminescent complexes of iridium(III) or osmium(II).

Compositions suitable for use as the carrier matrix (not shown) are oxygen-permeable compositions, preferably highly oxygen permeable compositions. One of routine skill in the art is capable of selecting such oxygen-permeable carrier compositions (not shown). A nonexhaustive list of polymers suitable for use as the carrier matrix (not shown) includes specifically, but not exclusively, silicone, polystyrene, polycarbonate, polysulfone, and some other polymers and co-polymers.

Use

The calibration tool **10** can be used to quickly and easily calibrate a fiber optic needle oxygen sensor **S** having an onboard oxygen sensitive photoluminescent probe **P** and programmed with a calibration mode. Calibration of the sensor **S** simply involves the steps of (1) setting the sensor **S** to calibration mode, (2) obtaining a span calibration value by (i) placing the photoluminescent probe **P** on the sensor **S** in fluid communication with a fluid having a known non-zero partial pressure of oxygen (typically atmospheric air known to have a stable concentration of 20.95% O₂), (ii) taking an oxygen concentration reading with the photoluminescent probe **P** onboard the sensor **S** in fluid communication with such fluid, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and (3) obtaining a zero calibration value by (i) placing the photoluminescent probe **P** onboard the sensor **S** in fluid communication with the chamber **29** of a calibration tool **10** by inserting the tip of the needle **S**₁ through the septa **31** covering the chamber **29**, (ii) taking an oxygen concentration reading with the photoluminescent probe **P** in fluid communication with the contents of the chamber **29**, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber **29**.

Correlation of each oxygen concentration reading to the proper calibration point (i.e., span calibration reading or zero calibration reading) can be accomplished in various ways. One technique is to take the oxygen concentration readings in a predetermined sequence previously input into the optical oxygen sensor **S**. A second technique is to provide the optical oxygen sensor **S** with additional data each time a reading is taken effective for indicating which calibration point has been or will be taken. A third technique is to provide the optical oxygen sensor **S** with additional data each time a reading is taken effective for indicating the oxygen concentration to which probe **P** was exposed at the time of the reading (e.g., user input of 20.95% O₂ after reading air and 0% O₂ after reading the chamber **29** of the calibration tool **10**).

I claim:

1. A calibration tool for use in obtaining a zero calibration value for a fiber optic needle oxygen sensor, comprising:

- (a) an open top vial constructed from an oxygen impermeable material and defining a chamber,
- (b) a resealing, needle-penetrable, oxygen impermeable septa sealingly engaged over the open top of the vial,
- (c) an oxygen permeable sachet containing a mass of particulate oxygen getter retained within the sealed chamber, and
- (d) a mass of an oxygen sensitive photoluminescent dye retained within and in fluid communication with the sealed chamber.

2. A method of calibrating a fiber optic needle oxygen sensor having an oxygen sensitive photoluminescent probe proximate the tip of the needle, comprising the steps of:

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- (a) setting the sensor to calibration mode,
- (b) obtaining a span calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with a fluid having a known non-zero partial pressure of oxygen, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and
- (c) obtaining a zero calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with the chamber of the calibration tool of claim **1** by inserting the needle through the septa on the calibration tool, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with the chamber of the calibration tool, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.

3. The method of claim **2** wherein the span calibration value and the zero calibration value are taken in a predetermined sequence.

4. The method of claim **2** further comprising the step of providing the oxygen sensor with data indicating whether a first reading was a span calibration value or a zero calibration value.

5. The method of claim **2** wherein the span calibration value is obtained by placing the photoluminescent probe in fluid communication with the atmosphere.

6. The calibration tool of claim **1**, wherein the oxygen getter is iron.

7. A method of calibrating a fiber optic needle oxygen sensor having an oxygen sensitive photoluminescent probe proximate the tip of the needle, comprising the steps of:

- (a) setting the sensor to calibration mode,
- (b) obtaining a span calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with a fluid having a known non-zero partial pressure of oxygen, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and
- (c) obtaining a zero calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with the chamber of a calibration tool in accordance with claim **6** by inserting the needle through the septa on the calibration tool, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with the chamber of the calibration tool, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.

8. The calibration tool of claim **6**, wherein the iron is an iron powder having an average particle size of 1 to 5 mil.

9. The calibration tool of claim **6**, wherein the weight/volume ratio of iron/ sealed chamber is 1:10 to 1:20 mg/cm³.

10. A method of calibrating a fiber optic needle oxygen sensor having an oxygen sensitive photoluminescent probe proximate the tip of the needle, comprising the steps of:

- (a) setting the sensor to calibration mode,
- (b) obtaining a span calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber, and (iv) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.

munication with a fluid having a known non-zero partial pressure of oxygen, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and

- (c) obtaining a zero calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with the chamber of a calibration tool in accordance with claim 9 by inserting the needle through the septa on the calibration tool, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with the chamber of the calibration tool, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.

11. The calibration tool of claim 1, wherein the vial is a glass vial.

12. The calibration tool of claim 1, wherein the vial is a small container.

13. A calibration tool for use in obtaining a zero calibration value for a fiber optic needle oxygen sensor, comprising:

- (a) an open top vial constructed from an oxygen impermeable material and defining a chamber,
 (b) a resealing, needle-penetrable, oxygen impermeable septa sealingly engaged over the open top of the vial, and
 (c) an oxygen permeable sachet containing a mass of particulate oxygen getter retained within the sealed chamber,
 (d) wherein the septa includes an oxygen barrier layer laminated to a layer of resealing elastomer.

14. A method of calibrating a fiber optic needle oxygen sensor having an oxygen sensitive photoluminescent probe proximate the tip of the needle, comprising the steps of:

- (a) setting the sensor to calibration mode,
 (b) obtaining a span calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with a fluid having a known non-zero partial pressure of oxygen, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and

- (c) obtaining a zero calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with the chamber of a calibration tool in accordance with claim 13 by inserting the needle through the septa on the calibration tool, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with the chamber of the calibration tool, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.

15. The method of claim 14 wherein the span calibration value and the zero calibration value are taken in a predetermined sequence.

16. The method of claim 14 further comprising the step of providing the oxygen sensor with data indicating whether a first reading was a span calibration value or a zero calibration value.

17. The method of claim 14 wherein the span calibration value is obtained by placing the photoluminescent probe in fluid communication with the atmosphere.

18. The calibration tool of claim 13, wherein the oxygen barrier layer is aluminum foil.

19. A method of calibrating a fiber optic needle oxygen sensor having an oxygen sensitive photoluminescent probe proximate the tip of the needle, comprising the steps of:

- (a) setting the sensor to calibration mode,
 (b) obtaining a span calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with a fluid having a known non-zero partial pressure of oxygen, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and

- (c) obtaining a zero calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with the chamber of a calibration tool in accordance with claim 18 by inserting the needle through the septa on the calibration tool, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with the chamber of the calibration tool, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.

20. The calibration tool of claim 13, wherein the elastomer is a synthetic silicone rubber.

21. A method of calibrating a fiber optic needle oxygen sensor having an oxygen sensitive photoluminescent probe proximate the tip of the needle, comprising the steps of:

- (a) setting the sensor to calibration mode,
 (b) obtaining a span calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with a fluid having a known non-zero partial pressure of oxygen, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with a fluid having a known non-zero partial pressure of oxygen, and (iii) correlating the oxygen concentration reading with the known non-zero oxygen partial pressure, and

- (c) obtaining a zero calibration value by (i) placing the photoluminescent probe of the sensor in fluid communication with the chamber of a calibration tool in accordance with claim 20 by inserting the needle through the septa on the calibration tool, (ii) taking an oxygen concentration reading with the photoluminescent probe in fluid communication with the chamber of the calibration tool, and (iii) correlating the oxygen concentration reading with the known near zero oxygen partial pressure in the chamber.